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Maturity of ERS power transfer technologies

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Summary

There are numerous promising Electric Road System (ERS) development and demonstration projects globally since several years. However, the investment cost for large-scale deployment of ERS is considerable and decision-makers will require knowledge about how mature different solutions are compared to other transportation solutions. Drawing on the method associated with Technology Readiness Levels (TRLs) and previous efforts, this abstract provides a maturity assessment of several electric road system (ERS) technologies with a focus on the power transfer technology subsystem.

1 Research Questions

An implementation of a particular Electric Road System (ERS) solution will involve considerable investments and imply a significant transformation of transport systems, e.g. regarding how road vehicles are designed and used. Decision-makers therefore needs to be ensured that the chosen ERS solution works satisfactory and fulfils its promises, i.e. is mature for the intended purpose. This is no different from past technology transitions. Different ERS technologies are evolving and are becoming more defined and mature systems, but how to assess the maturity of a solution and how can different solutions be compared? This article investigates two research questions:

- How can the technical maturity of different ERS solutions be assessed?
- What is the technical maturity of different power transfer solutions for ERS?

The basic technologies for electric power transfer from the road to vehicles in motion have been developed through various research and development projects across the globe. ERS is currently tested and demonstrated in several forms at test facilities and on public roads, and there starts to be a lot of available knowledge.

2 Methodology

NASA invented Technology Readiness Levels (TRLs) in the 1970s and made further developments in the 1980s and 1990s as described by Banke [1]. Other organizations have continued the development and the U.S. Department of Defense (DoD) has with its guidance for Technology Readiness Assessment (TRA) described “a systematic, metrics-based process that assesses the maturity of, and the risk associated with, critical technologies” [2]. Technology Readiness Assessment (TRA) is today an established method of estimating the maturity of a technology system for a given application. The first step in a technology readiness assessment is to analyze the different elements of the system and identify the critical technology elements (CTE). The next step is to estimate the maturity of each CTE for the application following a well-defined

TRL scale. Finally, an aggregated maturity estimation using the TRL scale is made for the system. The definitions of the nine levels are as follows:

TRL 1. Basic principles observed and reported.

TRL 2. Technology concept and/or application formulated.

TRL 3. Analytical and experimental critical function and/or characteristic proof of concept.

TRL 4. Component and/or breadboard validation in laboratory environment.

TRL 5. Component and/or breadboard validation in relevant environment.

TRL 6. System/subsystem model or prototype demonstration in a relevant environment.

TRL 7. System prototype demonstration in an operational environment.

TRL 8. Actual system completed and qualified through test and demonstration.

TRL 9. Actual system proven through successful mission operations.

The U.S. Department of Defense has also developed Manufacturing Readiness Levels (MRLs) intended for production contexts [3]. However, the technology and manufacturing perspectives are not the only relevant perspectives while assessing the potential and possibility for large-scale deployment and usage. Market and social acceptance are for example also important.

The TRA method has proven to be a useful method for assessing the technical maturity of ERS, as shown e.g. by Sundelin et al. [4] and Gustavsson et al. [5]. One important part of the methodology work has been to examine how the TRL definitions and descriptions from U.S. DoD's TRA guidance shall be applied to an ERS context, i.e. determine useful and clear meanings of "relevant environment", "operational environment", "system model", and "system prototype". The result is as follows:

- TRL 5. Component and/or subsystem validation along test track and subject to any realistic weather condition.
- TRL 6. Demonstration vehicle propelled by power from ERS equipment along test track and subject to any realistic weather condition.
- TRL 7. Demonstration vehicle with prototype power receiver, running at typical operational speeds along a public road during any realistic weather condition, and propelled by power provided by a prototype power transfer subsystem installed in vehicle and deployed along the public road.

In addition, for TRL 8 the U.S. DoD's TRA guidance gives the following useful description "Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. […]".

A maturity assessment following TRA "by the book" requires access to subject matter experts and supporting information such as test data. Instead, the authors have in the present work made a simplified technology readiness assessment of different ERS power transfer technologies using public information available in December 2019.

The basis for the present assessment is the application of ERS for heavy duty vehicles operated at speeds normally occurring on country roads and highways, and subject to realistic weather conditions for Northern Europe. At the moment, only two ERS technologies have been demonstrated for this application and during at least one summer and one winter season. The progress of these demonstration activities has been reported by Region Gävleborg [6] and eRoadArlanda [7], respectively. These two demonstrations and also other projects have been closely followed by the authors.

Through an analysis of the different elements of a general electric road system, the critical technology elements can be identified. The analysis shows that all subsystems are critical in order to ensure high quality service and high uptime of the total system, but the power transfer subsystem is found to be the most fundamental for the ERS concept and also includes electrical hazards and the least proven components.

3 Results

System prototypes of the overhead-line technology from Siemens have been demonstrated for over three years along a public highway as reported by Region Gävleborg [6]. The first system prototype version has TRL 7 and there are components such as the overhead lines that are believed to have TRL 8. However, the power receiver and its control have recently been redesigned due to lessons learned. The new system prototype version has TRL 6 and needs to be demonstrated during winter conditions before the system can be said to have completed TRL 7.

Alstom ERS has TRL 5 since the power transfer components have been integrated and validated to work together at a test track. There is no public information about demonstration of vehicle propulsion. It is however believed that Alstom is able to perform a quick maturity development.

The Elways technology has at least TRL 6 since a system prototype have been demonstrated for more than one year along a public road as reported by eRoadArlanda [7]. There have been several improvements of both installation and technology during the demonstration time period, and these improvements have to be validated before the system can be said to have completed TRL 7.

The Elonroad technology has TRL 5 since the power transfer components have been integrated and validated to work together at a test track. The new design with the rail in the road surface level has TRL 4.

The Honda technology with an ERS lane on the side of the road has TRL 4 when considered as a system. Some technical components have TRL 5.

The technology from Bombardier has TRL 5 since the power transfer components have been integrated and validated to work together at a test track. Some components have however not been fully integrated in the vehicle.

The OLEV technology is found to have TRL 7 for the application of urban buses, even though the available test result information is limited and there might be challenges that imply TRL 6 in reality. The technology has TRL 4 for long-range and high-speed applications.

The technology from WAVE and the technologies studied in the FABRIC project have not been considered due to lack of available information.

The Electreon wireless technology has TRL 4. A rapid maturity development is expected in order to be able to perform demonstrations in an operational environment within a year.

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